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MODEL BORNE DATA MANAGEMENT SYSTEM FOR WIND TUNNEL TESTING

PHASE II SBIR FINAL REPORT

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13. ABSTRACT (Maximum 200 words)

This report covers the development of a modern model mounted wind tunnel data acquisition and processing system called MDARS, short for Modular Data Acquisition and Recording System. During this Phase, prototypes of the model borne components and the pc interface were developed. The system was then installed in a HP-MaRV model for demonstration testing in AEDC's wind tunnel B. Following these tests the performance and durability of the system was analyzed and lessons learned were identified and incorporated into a production version of the system. These activities resulted in a proven data system, ready for marketing.

The MDARS uses modern high density surface mount components in a compact modular/bus arrangement which allows a size which can be accommodated by most wind tunnel models. It also allows the system to be controlled and data to be acquired by a modern personal computer thus decreasing or eliminating dependence on facility data systems. The system multiplexes all data channels and converts all analog signals to digital. The remote system communicates with the Contol Personal Computer by fiber optic cable. The use of MDARS will reduce facility data system dependence while reducing test set up costs and schedule delays.

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INTRODUCTION

TeSCO, Inc., with support from Wright Patterson Air Force Base, has developed and demonstrated new techniques and data acquisition hardware for wind tunnel testing. TeSCO developed a Model bourne Data Acquisition and Recording System (MDARS) to streamline model preparation and reduce the time necessary to collect data on an aerodynamic model. Figure 1 shows the MDARS installed in a test model ready for demonstration testing in AEDC's Tunnel B.

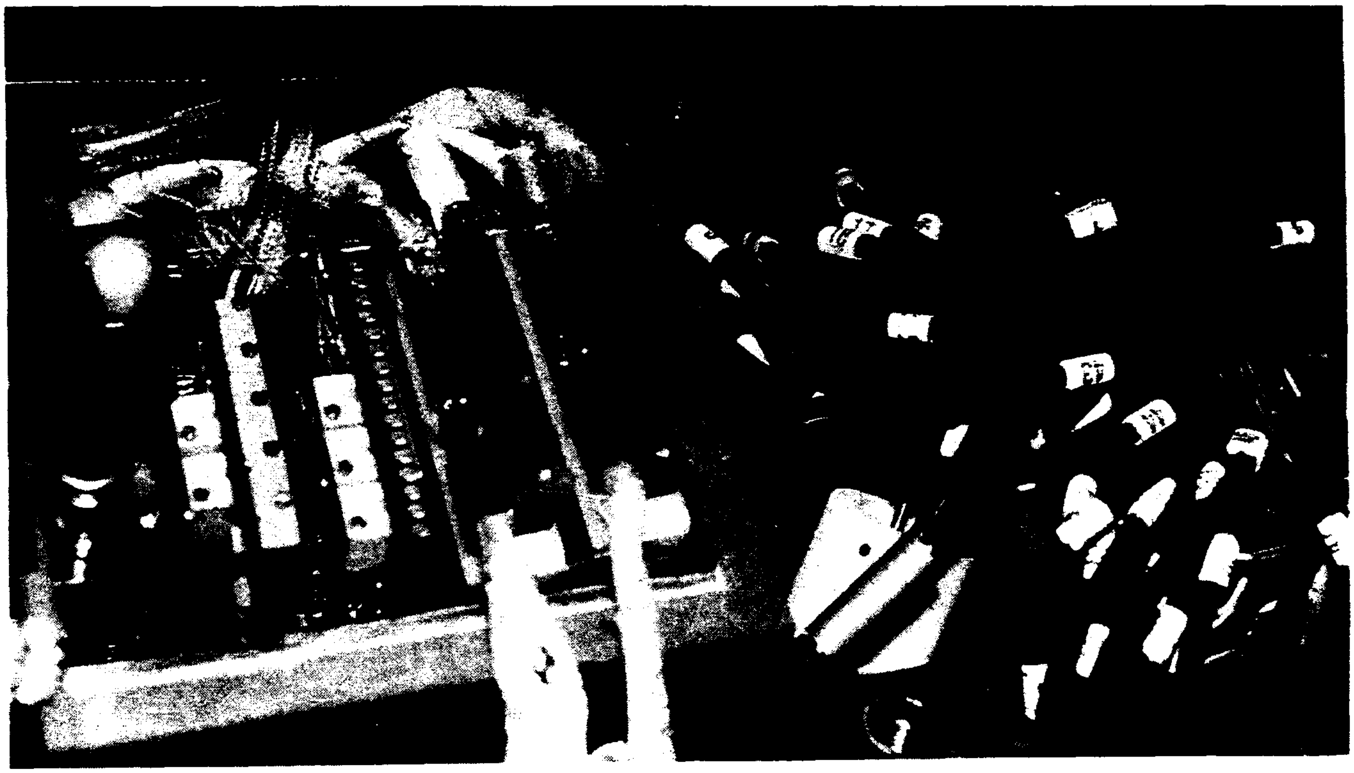

FIGURE 1
TYPICAL MDARS MODEL INSTALLATION

The model used was a high performance maneuvering reentry vehicle (HP-MaRV). This 40 inch, 140 pound stainless steel model was previously tested in VKF at Mach 8 in 1991 using the standard test procedures. For this project, the model was tested at Mach 6 with MDARS acquiring heat transfer, pressure and force measurements during a single tunnel entry.

The Wind Tunnel testing was done at the Arnold Engineering Development Center (AEDC), Tullahoma TN. The testing was conducted in Tunnel B of the Von Karman Facility (VKF) which is a high temperature, three dimensional, variable density (Mach number 6 or 8), continuous flow wind tunnel. Since the air flow stagnation temperature in this tunnel is very high (approximately 800-900 deg. R), most wind tunnel models must be temporarily removed from the hot air stream and cooled between test sequences. In this test, the model was injected (placed into the air stream) for approximately one minute and then removed to a cooling chamber to limit excessive model temperature, and to facilitate heat transfer data acquisition. (Reference 1).

The results of the AEDC testing were carefully analyzed to determine the performance and durability of the system. An update of the hardware and software was then undertaken to optimize the system for initial production.

Test Configuration

The MDARS is a computer based miniature data acquisition system developed primarily for wind tunnel model testing. The compact size of the MDARS installed inside the model enabled a single wind tunnel model to be instrumented for simultaneous heat transfer, pressure, and force measurements, whereas previously, individual models would have to be instrumented uniquely for each measurement. The use of the MDARS also lends portability; i.e. the data acquisition system is model oriented (separated from the wind tunnel), allowing the use of the same model instrumentation and data acquisition system in successive test facilities. The MDARS is not limited to the wind tunnel model applications. The MDARS design is applicable to any requirement in which portability or small size is important.

The MDARS wind tunnel model configuration is illustrated in Figures 2 and 3. A remote unit, located in the model, serializes, amplifies and digitizes the transducer signals. The digitized signals are sent to the MDARS control computer (PC) through a fiber optic data/command link running through the sting support. The MDARS control computer is also used for data reduction and analysis. MDARS power was provided by a cable routed from an external power supply (+ and - 15 volts) to the remote unit.

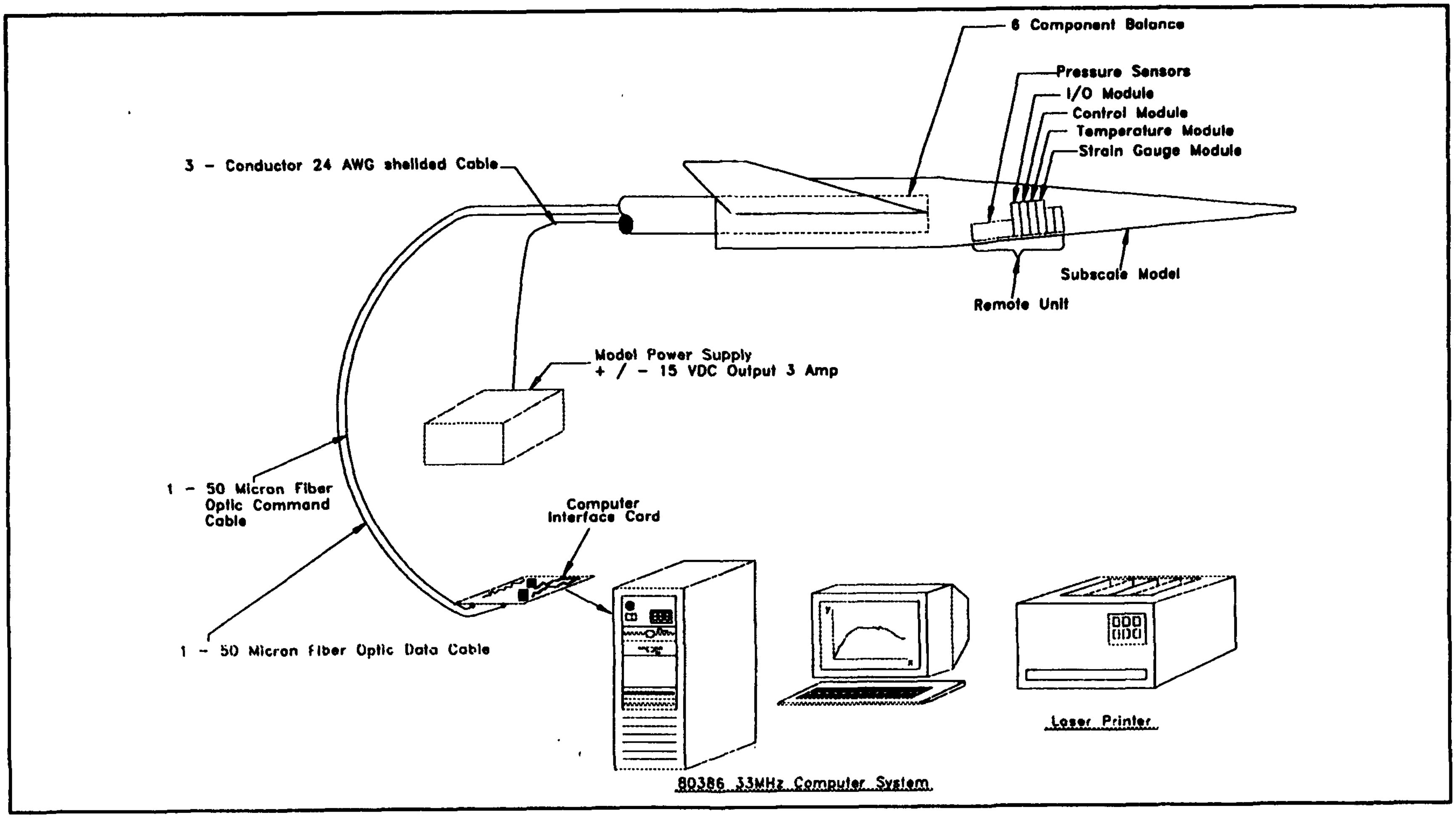

FIGURE 2
MDARS WIND TUNNEL MODEL CONFIGURATION

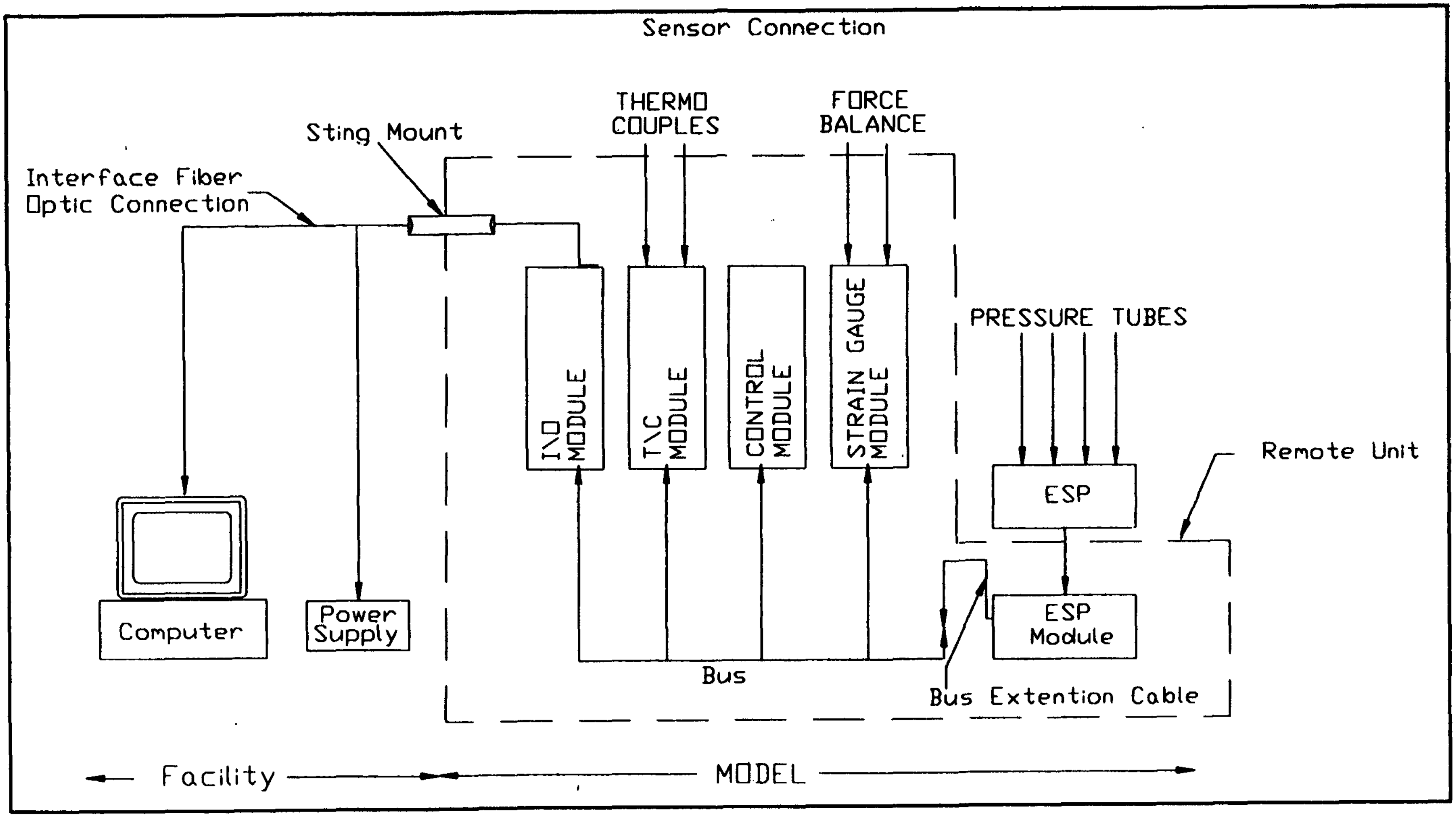

FIGURE 3
MDARS SYSTEM SCHEMATIC

MDARS Design Consideration

MDARS was conceived as a solution to the high cost of wind tunnel operations in support of aircraft development. Two problems related to testing expense were addressed by the MDARS concept. The first relates to the difficulty of getting data from a small model, and the second relates to the portability of the data acquisition hardware and software between facilities. The MDARS enables significant cost savings in both areas by reducing required tunnel and model preparation time and by reducing the number of required tunnel test entries and the required test time.

Wind tunnel models are used to obtain pressure heat transfer and aerodynamic force loading data. A model, mounted on a sting, has a restricted path through which tubes and instrumentation leads can be pulled, limiting the number of measurements that can be supported in any one test. Traditional methods require two to four leads for each thermocouple based heat flux gauge; power, address, and signal leads for each ESP (electronically scanned pressure transducer); and excitation, monitoring, and bridge output leads for each force balance. The limited number of sensors which can be supported through the sting typically results in the following scenario:

1) A model is initially instrumented for pressure measurements with one or more ESP's.
2) The model is tested, pulled from the tunnel, and reinstrumented for heat flux measurements.
3) The model is tested again in the tunnel.
4) The model is again pulled from the tunnel and instrumented for aerodynamic loading measurements.
5) The final test is performed in the tunnel.

Three instrumentation/testing cycles are required. The MDARS, by processing and multiplexing the data on the model, enables each of the three data sets (heat flux, pressure, and aerodynamic loading) to be acquired with one instrumentation/testing cycle. As a result, tunnel occupancy and operation costs could be reduced to one-third the previous costs for the same data by use of the MDARS.

Air vehicle development often requires subscale testing in a variety of conditions beyond the capabilities of any single tunnel. This is particularly true of high supersonic/hypersonic vehicles. Each different facility currently is equipped with its own Data Acquisition System (DAS), requiring a new interface with the model instrumentation and a unique data handling procedure. The use of the MDARS keeps the DAS and all data reduction/analysis software consistent and in the control of the organization requiring the model data. Since the same model hardware and supporting instrumentation and software is readily carried to the various

facilities, the need for instrumentation and data related support, external to the user project team is minimized.

Other MDARS Applications

The design of the MDARS, although initially optimized for wind tunnel model testing, allows application to a number of situations. The portability of the MDARS and the nature of the communication link between the remote unit and the computer make this data system suitable for most situations in which:

1) the data system and instrumented device are likely to be in one place for only a short while before being taken elsewhere for further testing, and;
2) access to the instrumentation from the data acquisition system is made difficult by space or distance restrictions.

A potential application of the MDARS, for example, is support of flight testing instrumentation. Aircraft are typically instrumented for flight testing at great expense, largely due to the difficulties in routing transducer leads from scattered locations on the airplane to a centralized data acquisition system. MDARS largely overcomes this problem since a few fiber optic cables can route information from multiple transducers of different types.

Future generations of the MDARS could incorporate telemetry and /or memory data storage to eliminate the necessity of the fiber optic and power supply links between the computer and remote unit. Either of these options would be viable, for instance, in road testing a race car. Data collected from the engine, drive train, or suspension would be telemetered to a receiver on the stationary computer, or simply stored until after a test run. In the latter scenario, the data analysis computer would interrogate the onboard RAM and download the stored data at the end of a test run.

MDARS HARDWARE DESCRIPTION

The MDARS is a modular data acquisition/controller system which multiplexes and digitizes multiple sensor generated analog signals and routes them to a data recorder computer via a fiber optic link. The MDARS also gives an operator keyboard control over transducer signal amplification, scan sequence and scan rate through the control computer.

The MDARS, shown schematically in Figure 3, is comprised of two major components:

1) the remote data processing unit and
2) the control and data acquisition computer

The remote unit consists of a bus connecting an I/O Module, a Control Module, and sensor interface Modules. The control computer is an IBM-PC compatible with either Intel 80486 or 80386 CPU. The MDARS requires a + and - 15 V power supply.

Remote Unit

The remote unit is built from modules which plug into a bus (Figure 4). With the maximum number of sensor modules (16) installed on the bus, the remote unit occupies a volume of approximately 2¼ x 2 x 9 inches. The effective volume occupied by the remote will increase slightly as sensor leads are connected to the sensor modules. A unit with the least data acquisition capability will contain an input/output module, a control module, and one sensor interface module and would occupy a volume of approximately 2 1/4 x 2 x 2 inches.

Data acquisition capability increases with the addition of sensor interface modules to the bus. MDARS is designed to handle up to sixteen sensor interface modules. In this configuration MDARS can handle up to 1024 channels of data.

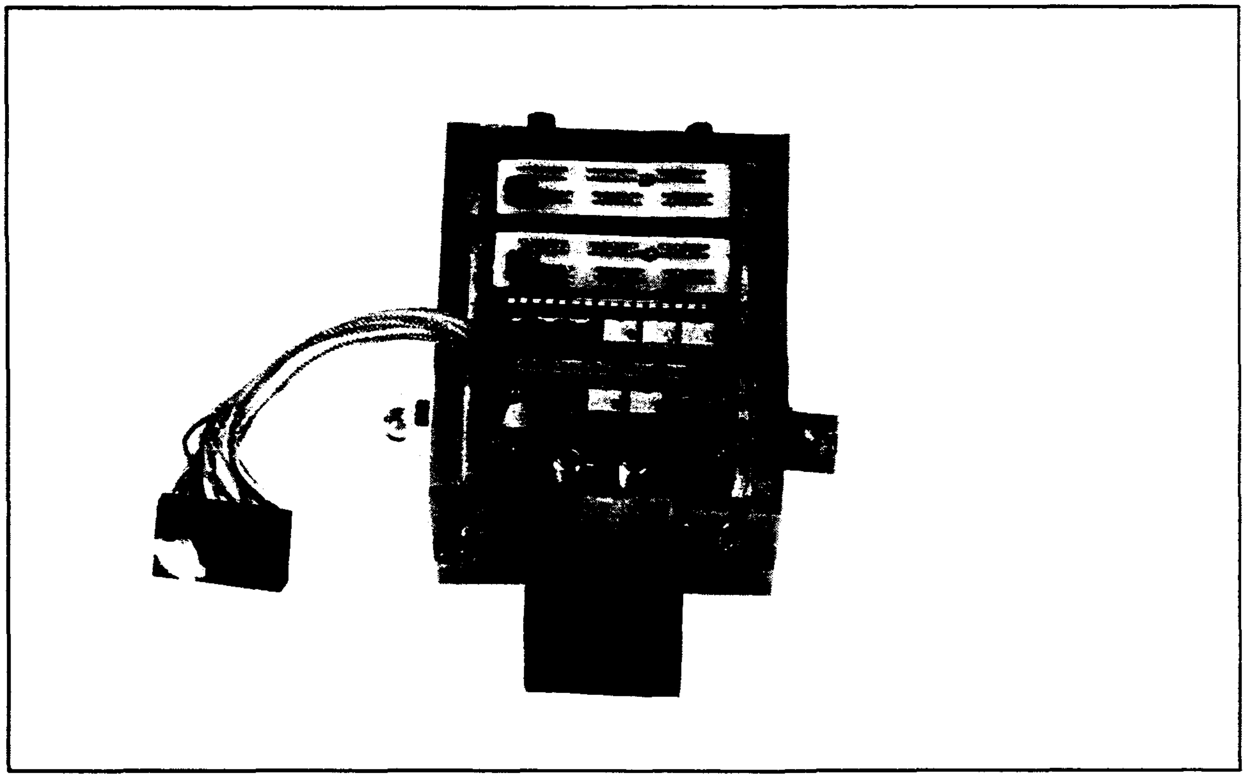

FIGURE 4
TYPICAL REMOTE UNIT

Input/Output Module

The Input/Output (I/O) module is the link between the remote unit and the computer. This module connects the power leads from the power supply and optical fiber cables from the Personal Computer. The I/O module is easily identified by the two fiber optic receptacles mounted opposite the bus connector (Figure 5). The I/O module provides the voltage regulation for the entire remote unit.

The ±15 volt power to the remote unit is supplied from a 3 amp power supply mounted outside the wind tunnel test section. The power is routed to the MDARS though a 22 AWG wire cable through the sting support. A battery could be installed within the model if desired to eliminate this cable from the sting. The power cable terminals and fiber optic cable receptacles are shown on the I/O module in Figure 5.

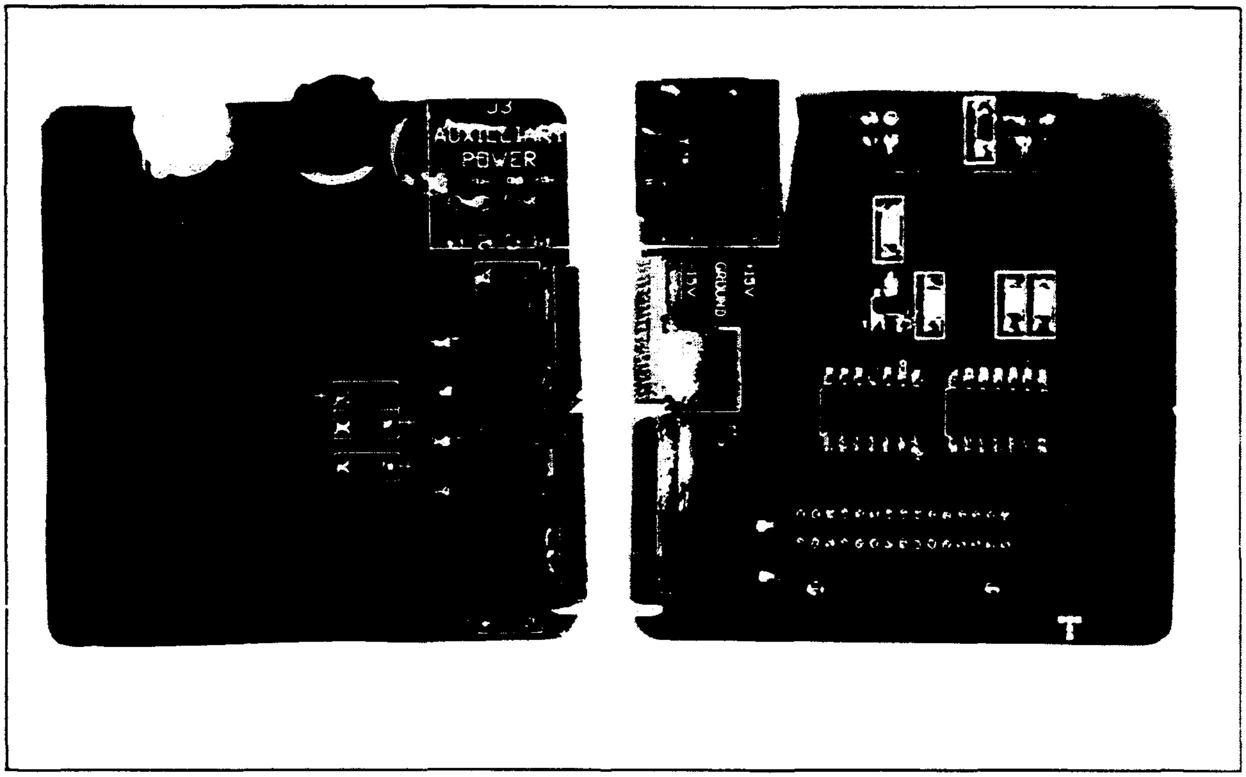

FIGURE 5
I/O MODULE

Control Module

The control module has no external connection other than the bus connector. This module provides analog signal processing and analog to digital signal conversion. The unit provides for final serialization of the data stream and controls all data opertions in the remote unit.

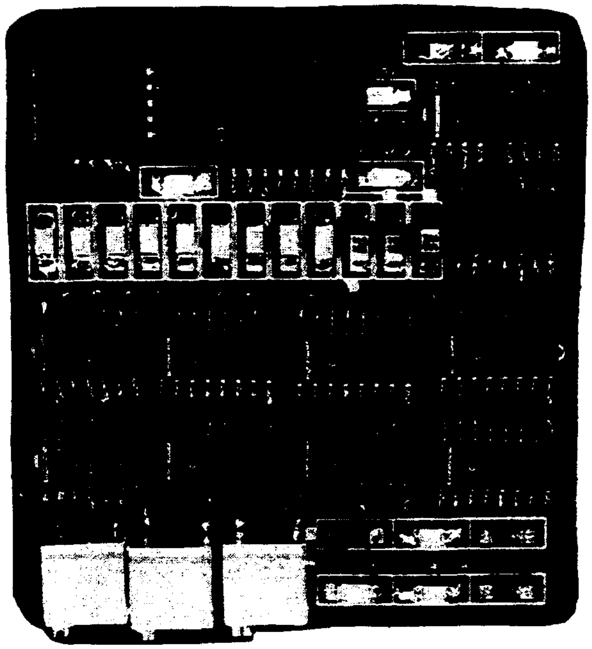

FIGURE 6
CONTROL MODULE

Sensor Interface Modules

Presently, three sensor interface modules are available: thermocouples, electronically scanned pressure (ESP) sensors, and strain gauges. As with the I/O and control modules, the sensor interface modules can be plugged into the bus in any order. The sensor interface modules, however, must be uniquely identified for data acquisition purposes, by assigning a number selected from one to sixteen. This is accomplished by setting a binary code switch on each of the sensor interface modules. The module identifying number is used in the data acquisition software for proper channel identification.

Thermocouple Module

Thermocouple (T/C) modules are equipped with a terminal connector on the end opposite the bus connector (Figure 7). The terminal strip has 90 female recepticals for insertion of 45 thermocouple wire pairs. Figure 8 shows how the thermocouple wire is mated to the terminal connector. A colored dot, about 1/8 inch diameter, indicates the position of an analog devices AD590 temperature microchip. The AD590 microchip is used to measure the temperature of the copper to thermocouple wire junctions, information which is needed in reducing the thermocouple millivolt signals to temperature indications. The module also has a 2.5 millivolt and a ground output signal for calibration purposes, hence each module is capable of producing 48 channels of information. The T/C module can also be used to measure any sensor output in the millivolt range by using the proper calibration.

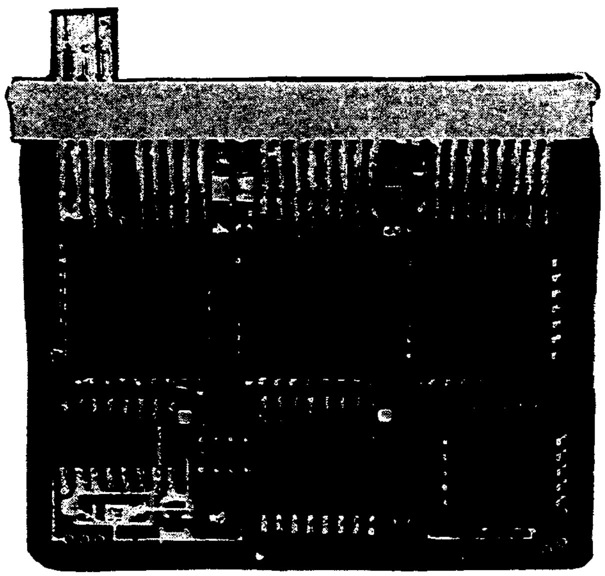

FIGURE 7
THERMOCOUPLE MODULE

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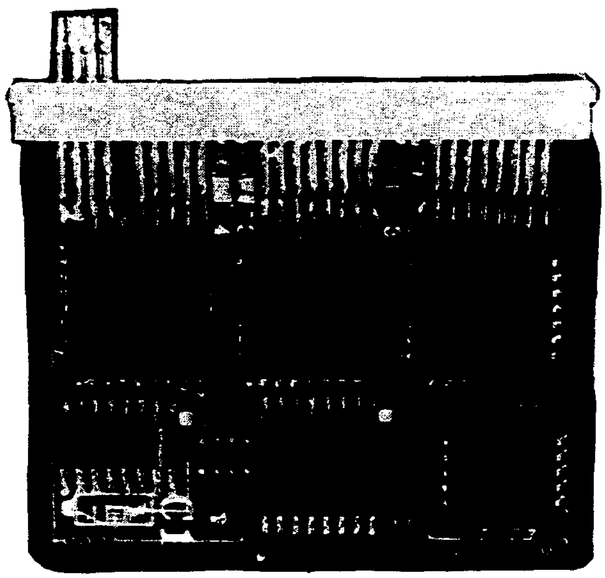


FIGURE 7
THERMOCOUPLE MODULE

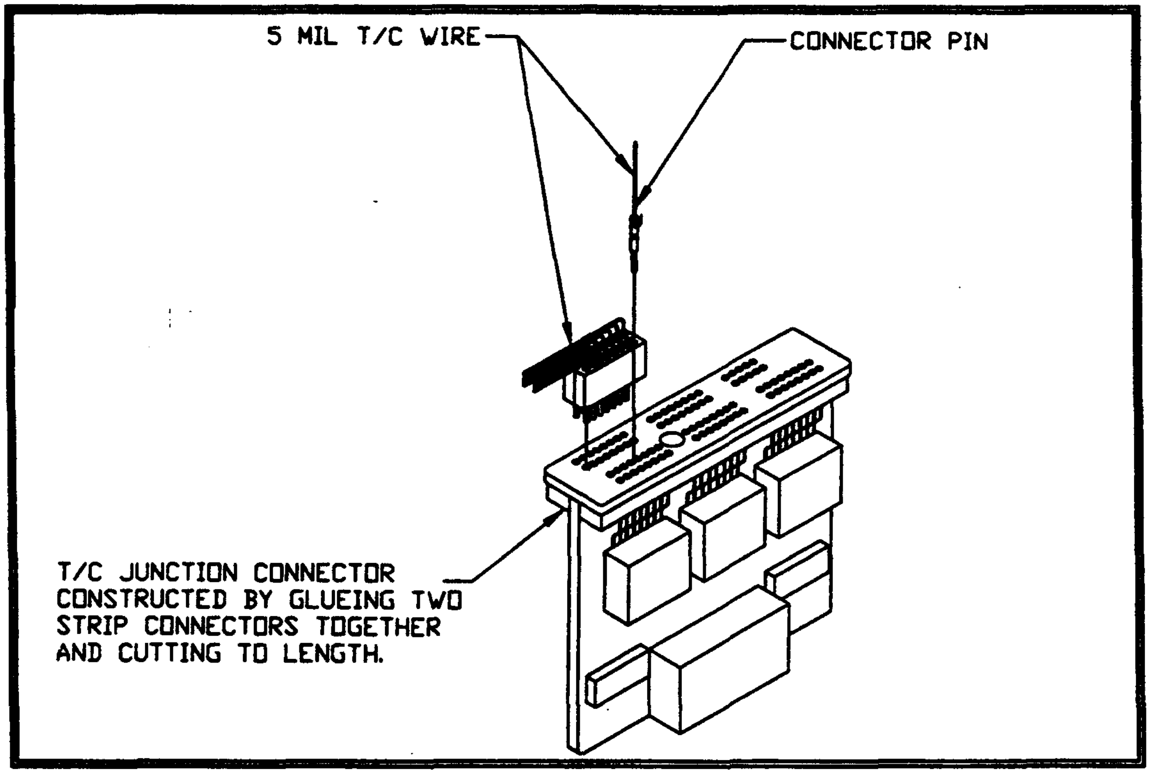


FIGURE 8
THERMOCOUPLE CONNECTOR FABRICATION TECHNIQUE

ESP Module

The ESP module is unique in its connection to the bus; the ESP module is designed to be located along side of the ESP and to be connected to the bus via a bus extension cable. The ESP module is then connected to the ESP by a second connector. The ESP module and bus extension cable are shown in Figure 9. An ESP module can address up to 64 ESP channels. Voltage regulation for the operation of the ESP is built into the ESP module. Heat rejection from the module is designed to provide direct heating of the ESP to temperature condition it for testing.

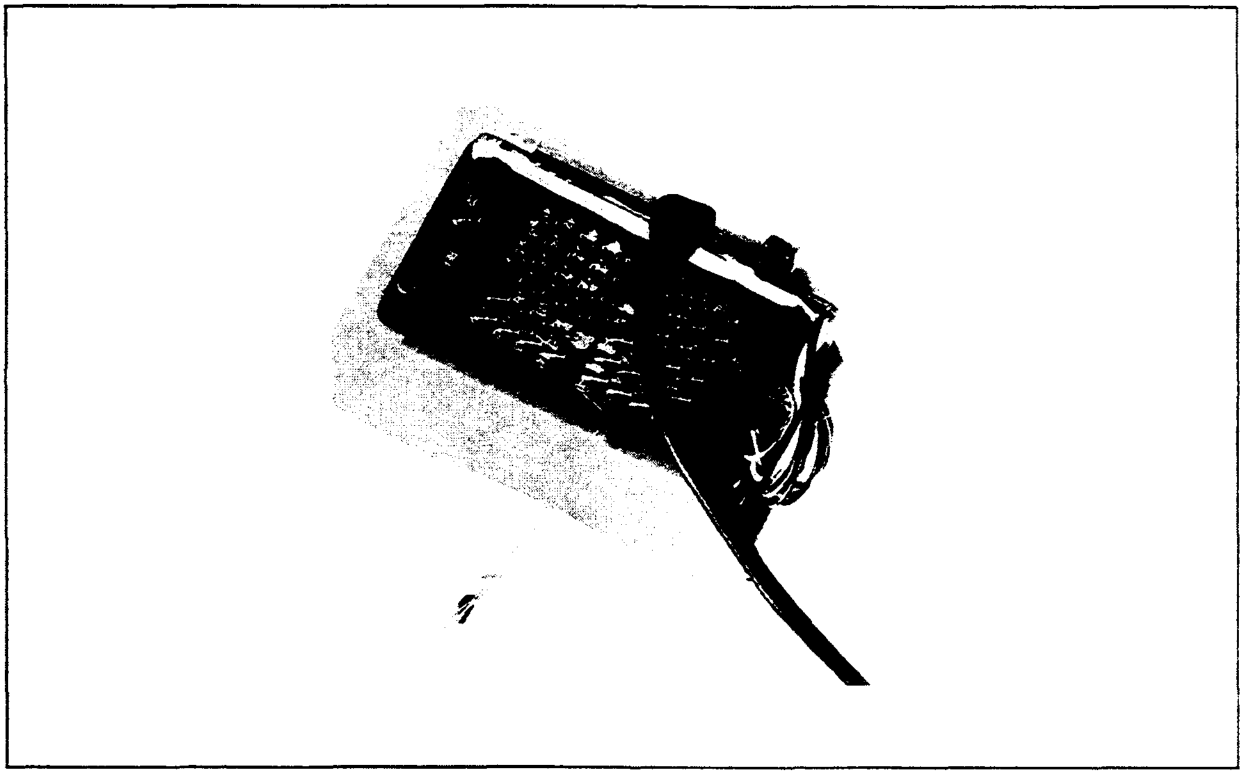


FIGURE 9
ESP MODULE AND BUS EXTENSIONS

Strain Gauge Module

The strain gauge module (Figure 10) is approximately the same size as the control module. The strain gauge module is designed to power and monitor six wheat stone bridges operating off the same regulated power. An 18 wire cable extends from the strain gauge module supplying excitation voltage, excitation monitoring, excitation control, and bridge output monitoring. Seven potentiometers on the module are used to adjust the bridge excitation voltage and the amplification of each bridge output. The bridge excitation voltage is controllable from 5 to 12 V.

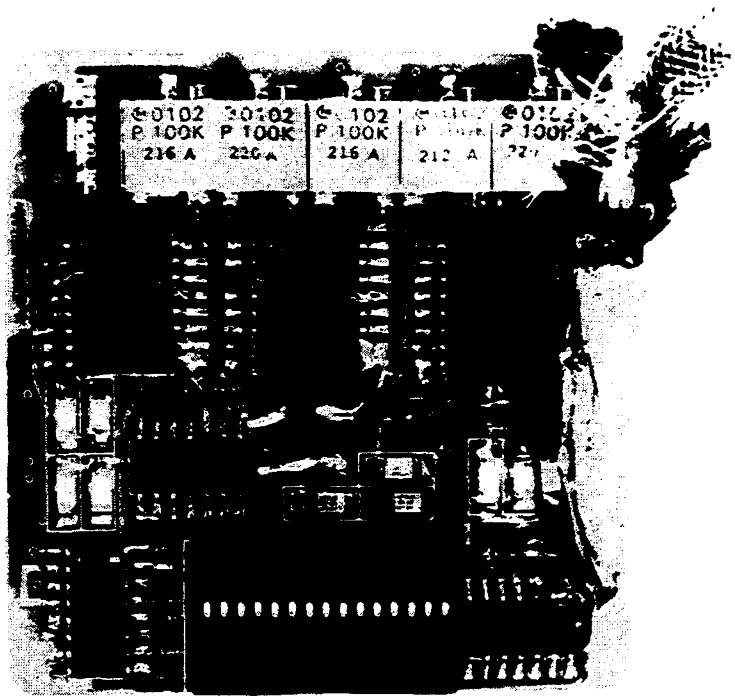


FIGURE 10
STRAIN GAUGE MODULE

MDARS Control and Data Acquisition Computer (PC)

The MDARS computer is an IBM-PC compatible with a 80386 CPU or 80486 CPU. The computer has an interface card which communicates with the remote unit and the software necessary for data acquisition and data reduction. The fiber optic cable communications link, with the remote unit, terminates on the computer interface card.

Through the data system drive and data acquisition software, the user created scan tables dictate which modules and channels will be sampled for data. The scan table also allows the user to dictate the order of the scan sequence, the channel amplification, and the time necessary for the data channel to "settle" before sampling. Real-time interaction between the user and the data acquisition program determines when data are recorded and the duration of data recording; i.e., whether a single slice steady-state data point or a time history of a transient phenomena is to be recorded. Multiple recordings of a single data channel are possible in the same scan sequence.

The data reduction software takes the output of the data acquisition software, raw counts, and converts that to nominal transducer output, or Engineering Units Data (EUD). Typically EUD output units from the thermocouple, ESP, and strain gauge modules will be, respectively; degrees Rankine, pounds per square inch, and bridge voltage.

DEMONSTRATION OF TEST CAPABILITY

Model Preparation

The HP-MaRV model was delivered to TeSCO, Inc. from WPAFB, without instrumentation installed except for the remains of the Schmidt-Boelter heat gauges used in the previous test. TeSCO, Inc. was to fully instrument the model and install the MDARS remote unit prior to delivery to VKF Tunnel B. This exercise was intended to develop procedures which might be used by an air vehicle developer in preparing a model for testing prior delivery to the test facility.

Prior to instrumentation by TeSCO, Inc., the model was taken to AEDC for internal modifications required to accommodate the MDARS remote unit. These modifications are shown in Figures 11A and 11B. Holes were bored in bulkheads for routing coax gauge leads and pressure tubes. Areas on the floor of the model were also prepared for installation of the MDARS remote unit and the ESP. This consisted of creating flat surfaces and threaded holes for the boxes built to hold the remote unit and the ESP unit. Ideally, the initial design of a model would provide for the installation of an MDARS unit.

AEDC provided a force balance (#5702) which was installed in a balance adaptor after checkout calibration in the VKF balance calibration laboratory. AEDC also provided a sting which was attached to the force balance. Stainless steel tubes were provided through the sting and balance adaptor for cooling water and vacuum pressure. The water supply and return lines were for cooling the balance and the remote unit. The vacuum line was for a reference for the ESP pressure measurments.

TeSCO installed 0.06" diameter coax heat flux gauges in the 3/16" holes made originally for Schmidt-Boelter gauges. To make the coax gauges fit, they were sleeved with steel jackets to fit the holes. The gauges were epoxied into place. The leads were routed to the approximate location of the remote unit in multiple bundles, secured to the model interior wall by epoxy. The coax leads were terminated with a connector appropriate to the T/C module. Instrumentation locations are shown in Figure 12.

The ESP with the ESP Module in physical contact was placed in a custom-made nylon box secured to the model floor. A heating blanket was not used, as the nylon box insulated the ESP from the heat input during test insertion and contained the heat generated by the ESP and ESP Module. This self-heating was used to maintain the electronics within the desired temperature range.

Viton tubes were used to connect ESP ports to model pressure ports. The pressure ports were the same as those used in the previous test. The plugs and steel tubes from two ports (which were located underneath the remote unit) were redesigned by TeSCO to lie flatter to the wall of the model. Thin walled Teflon tubes were connected to the ESP calibration ports C1 and C2 with the open end accessible through a flap at the rear of the model. This provided an in-place pressure calibration capability when the model was installed in the tunnel.

The balance adapter (with the balance and sting assembly) was installed in the model at TeSCO, Inc. The wiring harness from the force balance was shortened and routed from the sting back into the model to the strain module on the MDARS remote unit.

HP-MaRV Installation

For this test, the remote unit was installed in a water cooled box installed in an insulating glass filled nylon box. The nylon box provided protection from heat and vibration and was secured to the model floor with screws, as shown in Figures 11A AND 11B.

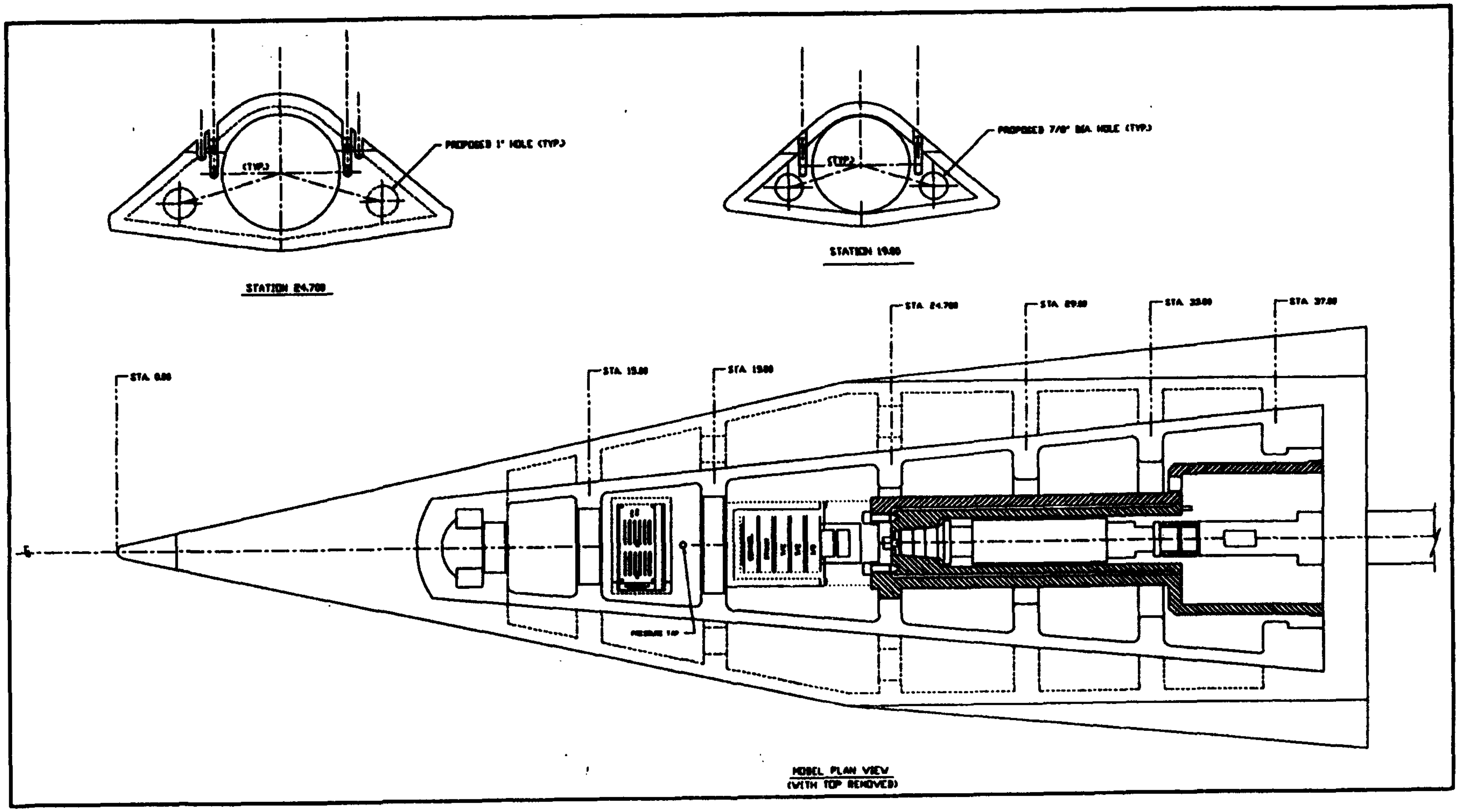


FIGURE 11A
HP-MaRV MODEL MODIFICATIONS

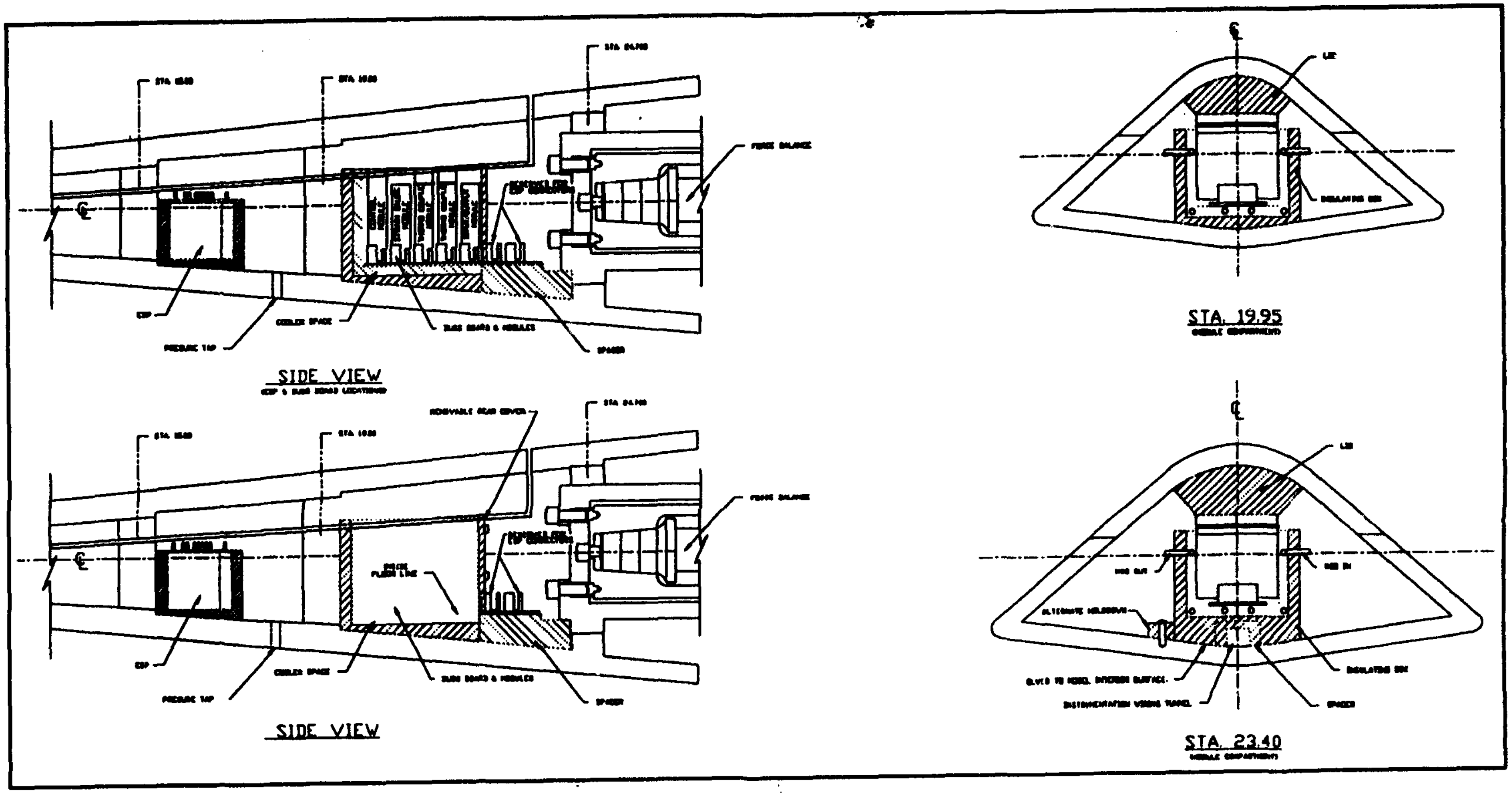


FIGURE 11B
HP-MaRV/MDARS INSTALLATION DETAILS

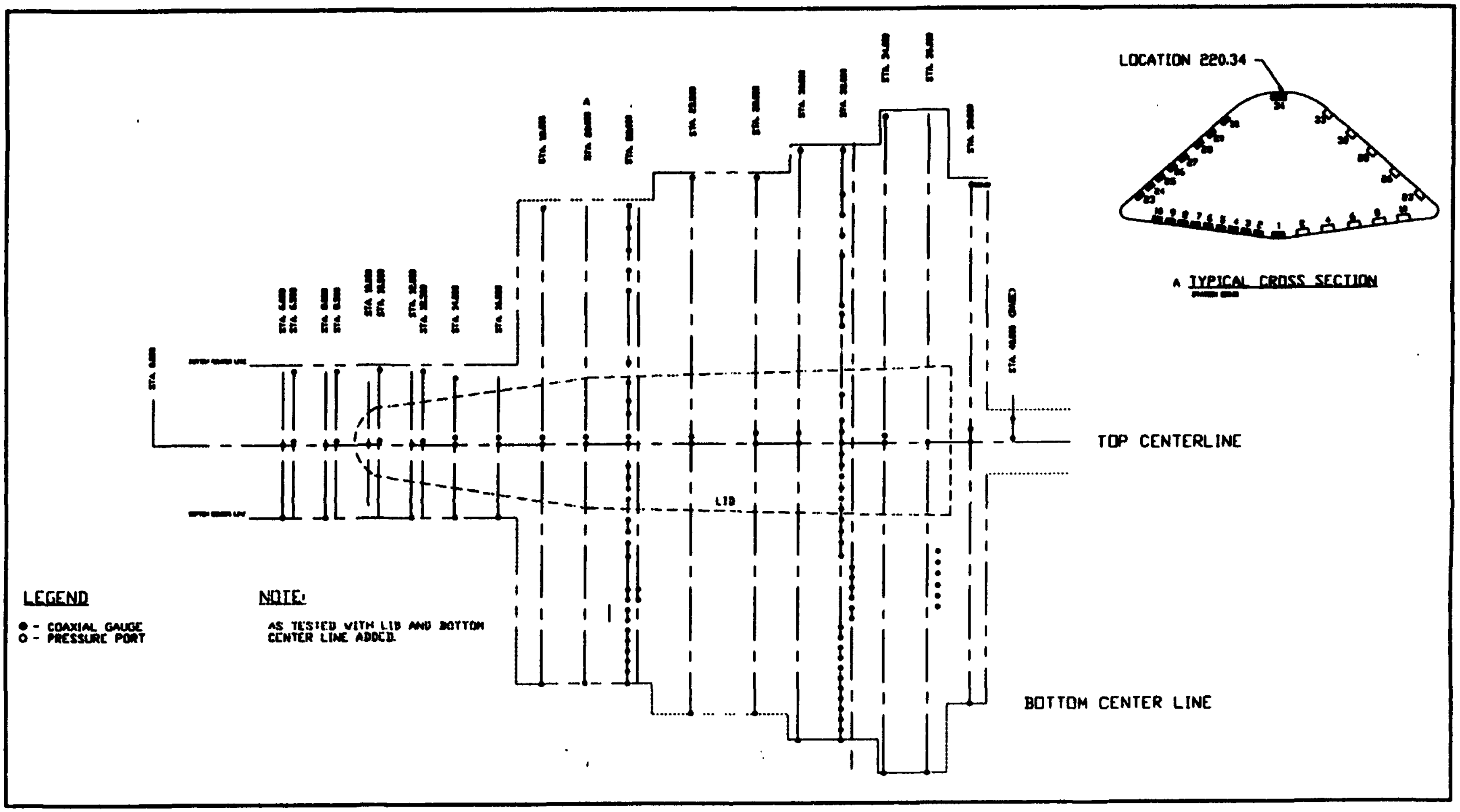


FIGURE 12
HP-MaRV INSTRUMENTATION LOCATIONS

Six thermocouples were used for monitoring temperatures internal to the model. One thermocouple was attached to the unanodized aluminum frame of the ESP. Two thermocouples were attached to the force balance water jacket and three were used to monitor model internal wall temperatures. Those three were located against the model interior wall near coax gauges 120.02, 255.01, and 220.10.

TeSCO, Inc. personnel verified the instrumentation hook up by applying a vacuum to each pressure port and a hot soldering iron to each thermocouple and noting the response on the MDARS outputs.

At this point, the model and MDARS were considered ready for checkout at AEDC before going into the wind tunnel.

PRETEST CHECK OUT

Upon satisfactory end-to-end checks of each data channel in TeSCO's shop, the model assembly was transported to AEDC. The model and the MDARS were set up and pre-test checked (for both hardware and software) in the VKF balance calibration laboratory. The model and sting were mounted on a balance support rig which simulated installation in the wind tunnel. MDARS power leads, fiber optic cables, water tubing, and a vacuum source were routed through the test rig and sting into the model. The fiber optic cables were then connected to the control computer.

End-to-end calibrations were made on the force balance strain gauges, thermocouple outputs, and pressure (ESP) outputs. The force balance was checked for tares and response to loads which were applied to the model to simulate tunnel loads at various angle of attack, yaw, and roll. These loads were produced by attaching weights to the model at various locations and model attitudes. Calibration data were obtained on the pressure and temperature system. Checks were made for leaks in internal pressure tubing. End-to-end thermocouple and pressure data checks were made to validate proper hook up. MDARS software was used during these calibrations to prove the entire system through the data recording and reduction process.

After installation of the model/MDARS in VKF Wind Tunnel B, vacuum and water line leak checks were made, pressure ports and thermocouples were again checked for proper channel placement. Facility inputs to MDARS (instrumentation required to relate test conditions to model test results) were made and checked. These inputs consisted of tunnel total pressure, total temperatures, static pressure, model pitch and roll angles, lift off and centerline indicators. Installed model tares were taken and compared to those taken in the balance calibration laboratory.

At this point, it was determined that the model and MDARS were ready for testing.

TEST DESCRIPTION

Two tests were made in the tunnel at simulated flight conditions. The first test lasted for about 3 air-on hours and was terminated due to a burst cooling water line. The second test, one week later, lasted 7 air-on hours during which a complete set of data was taken.

The first test was made with limited ESP data. Early in the first test, the display data on the MDARS controller indicated that the ESP was not addressing all transducers correctly. The decision was made to continue to test with the limited ESP data. It would later be determined that a simple fix to the ESP module cleared the addressing problem allowing full data acquisition during the second test period.

The test was aborted when, just prior to the fourth injection, a water line burst. The water line provided cooling to the MDARS and the force balance. The cause of the failure was determined to be rubbing of a flexible water line on a sharp edge of a passage hole in the balance adaptor assembly which eventually weakened the line.

As a result of wetting, both the force balance and the MDARS required minor repair. Enough data had been taken and processed to evaluate the system and allow correction of problems. All repairs and software problems were corrected and the pretest checkout was repeated in preparation for rescheduled testing.

The second test went well. Twenty two injections were made in the course of about 5 hours. No problems were encountered with the model or MDARS although at one point the ESP temperature rose to 170° F. This problem arose when the model cooling cycle was shortened to accelerate testing. Further high temperature operation was avoided by more extensive cooling of the model in the tank between injections. The quality of the data was unaffected by the ESP temperature excursion and the change in test procedure returned to the ESP temperature to target levels.

Acquired Data

A total of 22 injections were made with model configurations which included various flap angles, blunt and sharp noses, and two roll angles. Angle-of-attack was varied during each injection from -2 to 15 degrees employing both continuous sweep and pitch pause techniques.

The model configuration for each injection is summarized in Table 1. A "data point" number is also tabulated with each test configuration. The day of the month and time of day each injection is encoded in the data point number (for example), data point 22094852 was taken on the 22nd day at 09:48:52.

A sample Engineering Unit Data (EUD) is plotted in Figures 13 through 15 for, respectively, the force signals, pressures, and temperatures. These data were taken from the first injection of the second air on period (22094852). Note that only data from the first half of the injection are presented (i.e., increasing angle-of attack). Data was also taken while the model swept from +15 to 0 degree angle-of-attack.

A test data report was produced and transmitted to WPAFB (Reference 2).

TABLE 1
MODEL AND TEST CONFIGURATIONS
MDARS/HP-MaRV IN AEDC/VKF Tunnel B

MACH NO. =6
REYNOLDS NO. = 5 MILLION PER FEET

DATA POINT	FLAPS	α	ROLL ∠	NOSE
22094852	-10	SWEEP	0	BLUNT
22100423	-10	P-P	0	BLUNT
22101623	0	SWEEP	0	BLUNT
22102725	0	SWEEP	0	BLUNT
22104010	0	P-P	0	BLUNT
22105045	0	P-P	0	BLUNT
22110358	+10	SWEEP	0	BLUNT
22111310	+10	SWEEP	0	BLUNT
22112039	+10	P-P	0	BLUNT
22112948	+10	P-P	0	BLUNT
22120606	+20	SWEEP	0	BLUNT
22121717	+20	SWEEP	0	BLUNT
22122832	+20	P-P	0	BLUNT
22124003	+20	P-P	0	BLUNT
22125321	0	P-P	0	SHARP
22130243	0	P-P	0	SHARP
22131308	-10	P-P	0	SHARP
22132708	-10	P-P	0	SHARP
22133917	-10	SWEEP	0	BLUNT
22135030	-10	SWEEP	0	BLUNT
22141508	-10	SWEEP	+180	BLUNT
22142610	-10	SWEEP	+180	BLUNT

NOTES:
1. Sweep rate was approximately 1 deg/sec.
2. Sweeps were from -2 to +15 deg angle-of-attack (α).
3. Pauses during pitch-pause injections (P-P) were at 0, 5, 10, and 15 deg angle-of-attack.

FIGURE 13
MDARS/HP-MaRV, MACH 6 - FORCE DATA

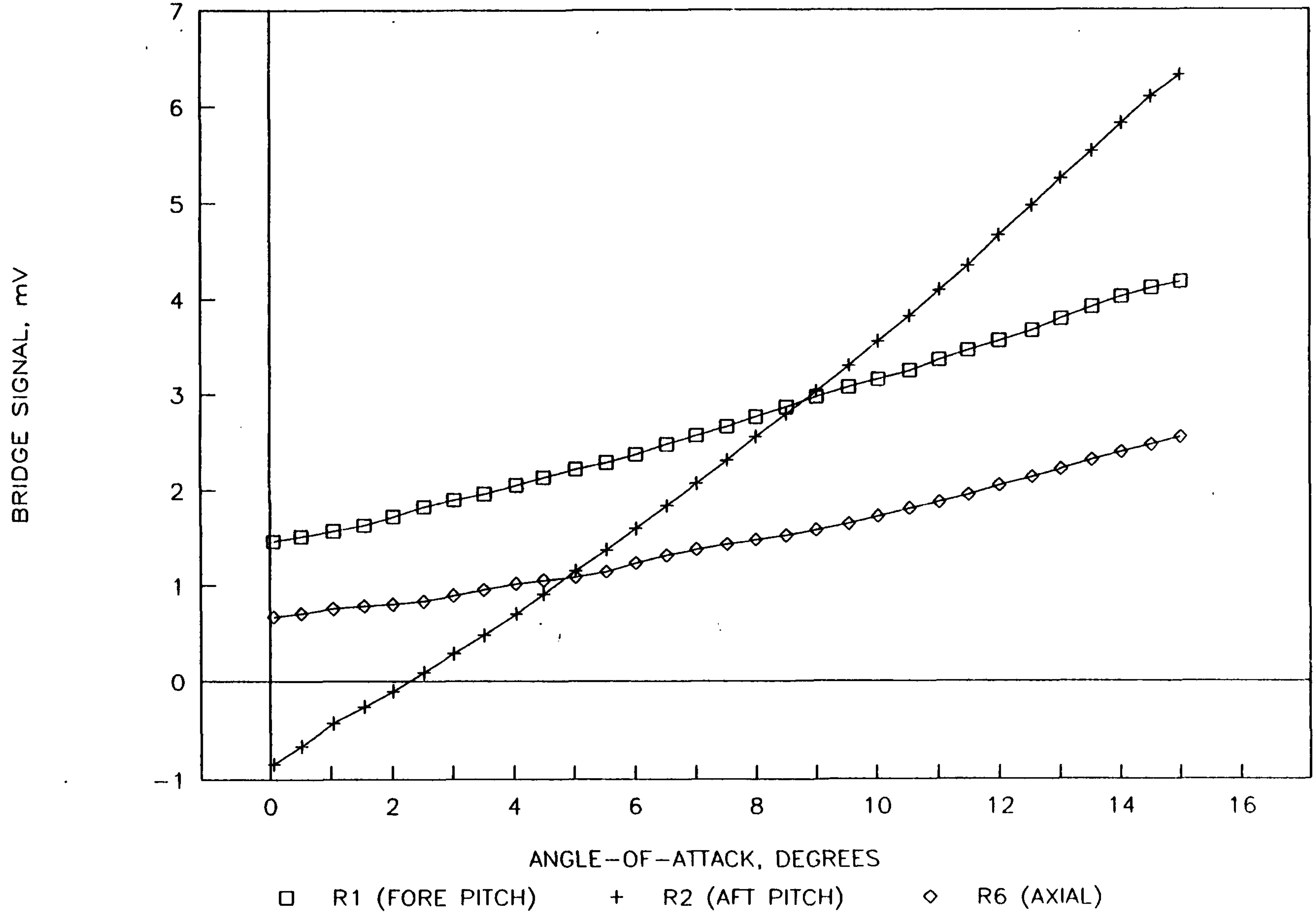


FIGURE 14
MDARS/HP-MaRV, MACH 6 - BOTTOM CENTER LINE PRESSURE

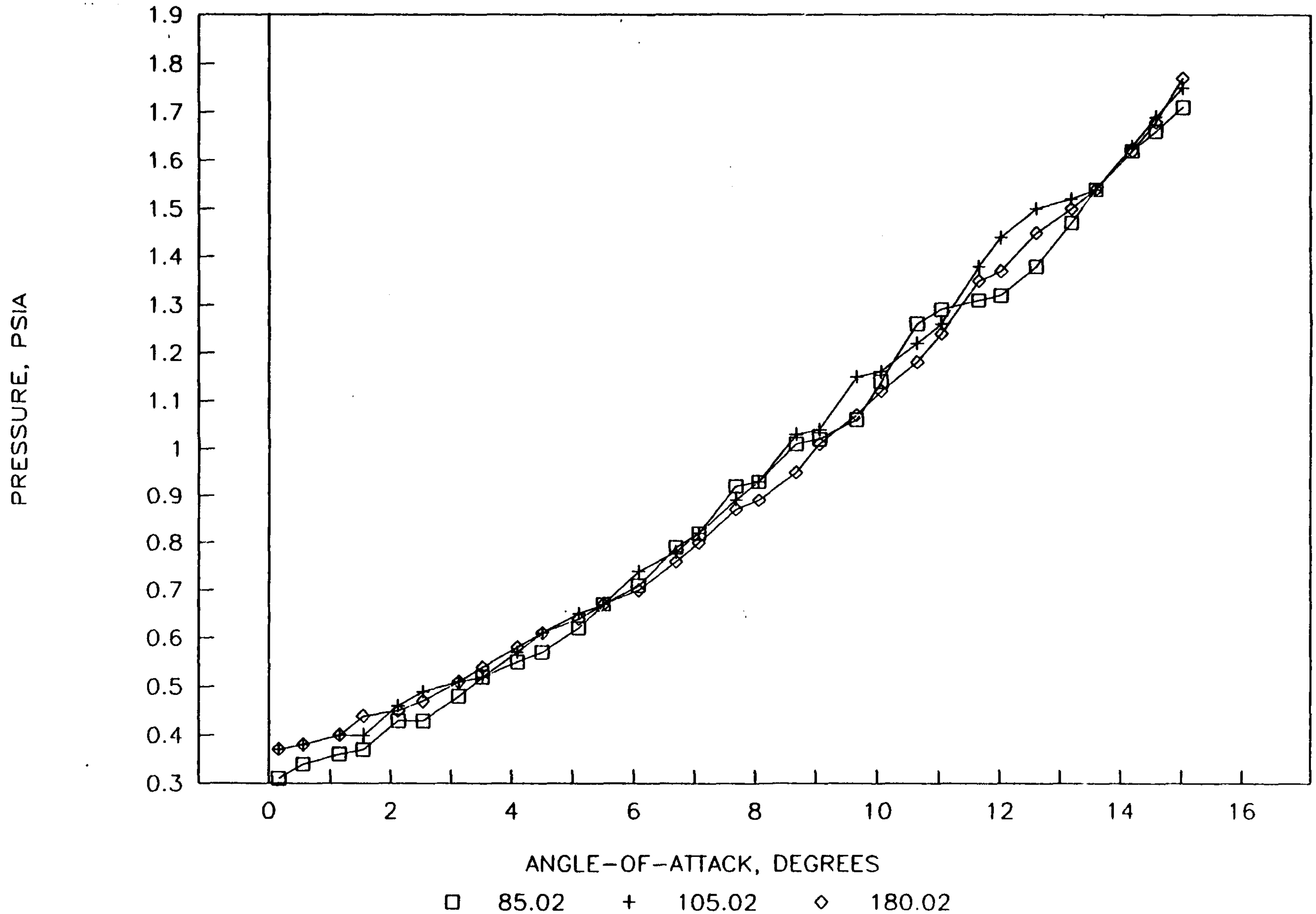
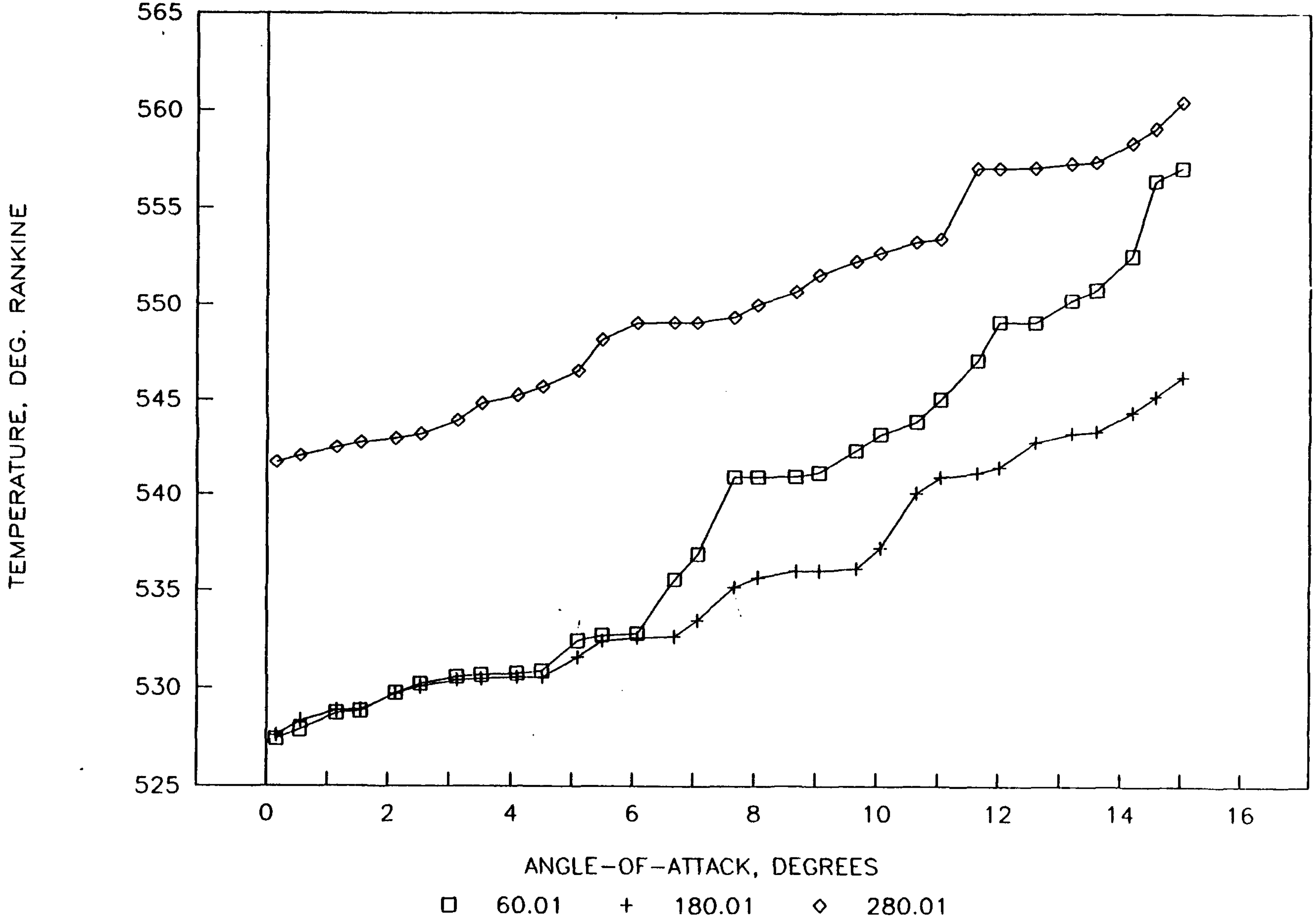


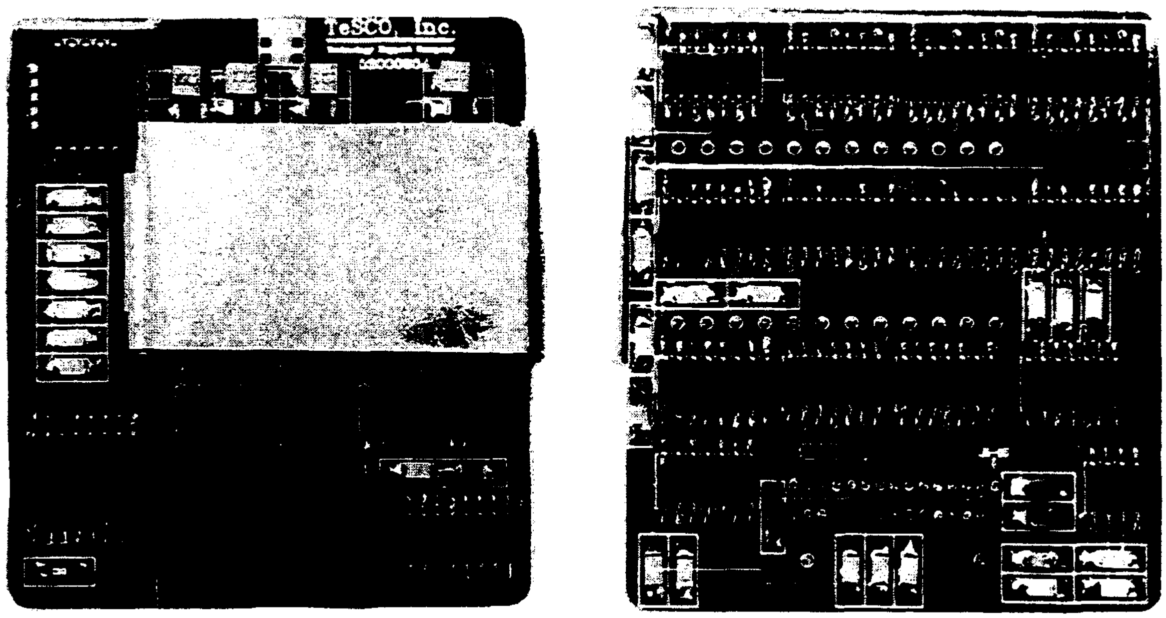
FIGURE 15
MDARS/HP-MaRV, MACH 6 - BOTTOM CENTER LINE TEMPERATURE



POST TEST ACTIVITIES

Following the demonstration test, the MDARS hardware and the test results were analyzed to ascertain performance levels and to identify areas that could be improved prior to finalizing the system for production.

A careful review of the data from the test indicated a lack of ability to resolve small signal changes which resulted from self induced noise during the analog to digital conversion process. This problem was eliminated by changing to a new A/D converter. The resulting production control module is shown in Figure 16.



FRONT BACK

FIGURE 16
PRODUCTION CONTROL MODULE

Other changes included changing to new fiber optic hardware with improved signal characteristics and better durability, and redesign to incorporate a rotary binary switch to provide module code information to the control computer. This change eliminated the binary plug which had been used during the AEDC tests thus, reducing the parts count for production sensor modules. This change is shown in a photo of the production T/C module in Figure 17.

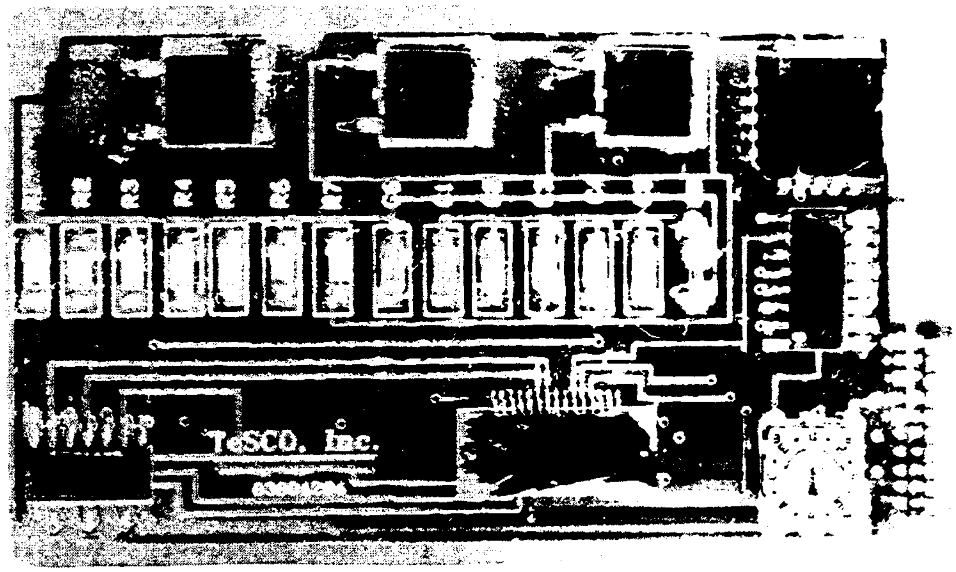


FIGURE 17
PRODUCTION ESP MODULE WITH ROTARY CODE SWITCH

To incorporate these changes all module circuit boards were redesigned and new production versions of all modules and the Personal Computer interface were constructed and tested.

Following completion of the testing of the production hardware, one complete hardware set was fabricated and shipped to Wright Laboratories and a second partial set was delivered to AEDC.

CONCLUSIONS

The main objectives of this program were to further develop the on-board miniature data system and to develop procedures for testing with an on-board model data system. Advances were made from a previous data system design, and all of the desired data was taken successfully. As of this writing, the quality of the data appears to compare favorably to that of the standard AEDC "facility" data system. TeSCO, Inc. will continue to evaluate the data quality as the MDARS development moves into Phase III. The following conclusions are devoted to comment about the procedure for testing with an on-board data system.

Overall, the preparation of the model, installation, calibration and testing went smoothly. This project was aided greatly by AEDC personnel.

Availability of a calibration test rig with a full range of actual wind tunnel model motions (angles of attack, roll, and yaw) would have facilitated checkout by TeSCO before going to the test facility. By the use of such a fixture a number of problems would have been identified and eliminated prior to shipment of the model, and a good deal of effort would have been saved. For any project using the MDARS in which the user instruments the model for force testing, TeSCO recommends access to such a rig for checkout prior to shipping the model to the test facility.

Special care in routing fiber optic cables is required. The fibers should always be allowed a generous turning radius around corners. The use of a conduit through the facility sting support system proved valuable in this test for protecting cables during installation. Beyond prevention, some steps should be taken in anticipation of broken fibers. These steps include ready availability of extra fibers, routing redundant fibers in initial installation, and having an on-site capability for repairing fibers.

Design considerations for a new model should include:

1) a space for the data system and a suitable surface for attaching the data system,

2) paths for routing transducer leads or pressure tubes from the model to the data system, and;

3) a path from the data system to the sting for routing data cables, system power, reference pressures, cooling water, and anything else necessary for supporting the test.

During design of high temperature test models using MDARS in conjunction with a force balance and the force balance water cooling jacket, consideration of the use of a single water cooling system capable of cooling both units should be given. In the MDARS/HP-MaRV test the wiring harness from the force balance by design went immediately into the sting. For the this test, the wiring harness was taken through a port in the sting, back through the model to the data system. Ideally, the wiring harness from the force balance would follow a more direct route to the data system, with the benefits of shortening the force balance leads and further reducing the "traffic" in the sting. Force balance design might also benefit from changes in the water jacket design to allow more direct cable routing.

Care should be taken to smooth rough edges and burrs. In this program a rough edge caused a water line to burst and a test was delayed. The water line (one of two) was used to supply a water jacket protecting the MDARS remote unit. Such water lines would probably be common in continuous hypersonic testing.

The initial production hardware, now available from TeSCO, Inc., incorporates lessons learned from the AEDC tests. Redesign of the modules has eliminated the noise problems encountered in the prototype and use of a new sample and hold A/D converter has improved accuracy. The use of the rotary code switch has eliminated the need for the individual code plugs used on the prototype. TeSCO, Inc. considers the development of this product complete at this time and is proceeding with marketing activities.

LIST OF REFERENCES

Reference 1: AEDC-TSR-93-V2 "Evaluation of an Onboard Modular Data System", by S. J. Rigney, dated April 1993.

Reference 2: Paige, T. S., "Test Report and Data Package for MDARS/HP-MaRV Test in VKF Tunnel B", submitted to Wright Patterson AFB, January 22, 1993 by TeSCO, Inc.